Case Study on Energy Strategy Concerning Santa Ana Wind Activity Triggering Fires in Southern California

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Abstract— **Santa Ana winds, which are characterized by their scorching, arid, and forceful surges, significantly exacerbate wildfire hazards in Southern California, extending to 23,000 ha, particularly in the Los Angeles region. The purpose of this study is to examine the correlation between anthropogenic influences and natural climatic phenomena, with a specific focus on the influence of regional energy policies on the frequency and intensity of wildfires. The interaction between the Santa Ana winds and landscapes that are becoming more flammable has become more intensive in recent decades, although they are a natural phenomenon. Inadequately regulated urban expansion, prolonged droughts, and elevated temperatures are the causes of this intensification. Utility companies explicitly link wildfire ignitions during wind events to their energy infrastructure, particularly above-ground power lines. Moreover, the crisis has been further exacerbated by inadequate utility modernization, delayed policy reforms, and limited investment in fire-resilient infrastructure. This study assesses the degree to which regulatory inertia and climate change interact to elevate the likelihood of wildfires by analyzing historical wildfire data, meteorological patterns, and the evolution of California's energy policies. In the face of escalating climatic extremes, the results underscore the urgent need for energy strategies that are forward-thinking and integrated and that prioritize environmental sustainability, conflagration prevention, and resilience.**

Keywords— Energy policies, Santa Ana winds, climatic extremes

I. Introduction

Southern California was previously at risk for wildfires; however, the extraordinary intensity as well as scale of the 2025 fire season brought attention to the relationship between climate behavior and energy policy [1]. The Santa Ana winds, which are naturally occurring katabatic winds, are essential to this crisis as they direct hot, dry air from inland deserts onto the coast, typically reaching their peak in autumnal periods [2]. Historically a part of the region's climate system, those winds now affect conditions characterized by heightened flammability due to extended drought, increasing temperatures, and human-induced alterations to the landscape [3]. Climate change has heightened the occurrence of extreme temperatures and modified precipitation patterns, establishing conditions conducive to ignition and swift fire propagation [4].

The aging energy infrastructure in wildland-urban interfaces worsens hazards associated with nature, as above-ground power lines frequently serve as ignition sources during extreme wind activities [5]. Investigations on major fires in 2025 indicate the fact utility-related sparks are actually the main triggers, reflecting prior incidents that included the 2018 Camp Fire [6]. Energy regulations have failed to keep up with the latest scientific and technological guidelines for grid hardening and fire prevention, despite a few policy recommendations and investigative reports [7]. Modernization efforts, which involve the undergrounding of power lines and the establishment of predictive shutoff systems, have encountered challenges that are caused by political inertia, financial constraints, and differing governmental requirements [8].

Moreover, rapid, frequently unexpected population growth into high-risk fire regions has increased vulnerabilities, which are worsened by insufficient zoning regulations and reactive emergency planning frameworks [9]. The growing energy demands associated with population growth, coupled with the strain on aging systems and insufficient oversight, create a dangerous circular cycle of risk and reactions [10]. The 2025 firestorms emphasize the significance of integrated policy reforms that relate to energy infrastructure planning, adaptation to climate change, and wildfire mitigation approaches [11].

This study attempts to break down the correlation among extreme climate conditions and energy-related policy difficulties in the state of California through a quantitative-methods approach that analyzes meteorological information, ancient fire statistics, and policy shifts over the past two decades. At last, it defends a reconsideration of energy adaptability as an essential component of adapting to climate change and wildfire risk prevention in today's world.

II. Methods

The research of "Case Study on Energy Strategy Concerning Santa Ana Wind Activity Triggering Fires in Southern California" will be carried out with the following data.

A. *Historical Data*

An analysis of the Santa Ana wind profile will be performed using historical data, taking into consideration the wind speed, direction of the breeze, temperature, and humidity as measured by meteorological stations.

B. *Correlation and Regression*

Correlation and regression methods based on meteorological data are used to link the Santa Ana wind events to the fire outbreaks that occurred in southern California.

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C. Energy Infrastructure and Policy Analysis

Utilized to assess anthropogenic factors, whether the failure of the aboveground electricity network contributed to the fire that occurred due to a short circuit that produced sparks.

III. Results and Discussion

A. Santa Ana Wind Profile

Southern California has a complex topography that makes it challenging for meteorological stations to measure the distribution of wind speed, wind direction, temperature, and humidity. To obtain an average Santa Ana wind profile, a total of 30 weather stations are required. The results of measurements by meteorological stations show wind speed data obtained from wind changes on days with and without Santa Ana winds, as well as on days with and without fires. Wind speed measurements on days without Santa Ana winds were weaker, both during and after fires (2.30 m/s and 2.38 m/s), although wind speeds on Santa Ana days with large fires (mean wind speed = 5.19 m/s) were much higher than on Santa Ana days without large fires (3.96 m/s) [12]. The speed of the Santa Ana wind moving from high-pressure areas to low-pressure areas is able to dry vegetation and create ideal conditions for fires, so that the area of fire will increase as long as there are still trees in the vegetation. The results of measuring the distribution of the direction of the Santa Ana wind flow by the meteorological station are shown in Table 1 below.

From the profile seen in the table, the Santa Ana wind speed seems normal and does not trigger the spread of fires. However, in some areas, Santa Ana gusts can reach speeds of 60–70 mph. The wind flow coming down from the mountains can be compressed at that speed. Because it comes from the desert, very dry wind gusts to relative humidity below 10%, compressed, can easily raise the temperature of the wind to warm, thus triggering the spread of fire areas in southern California.

Table 1. Average wind speed and direction observed at 30 meteorological stations in Southern California from 1996 to 2010 [12]

	Wind speed (m/s)	**Wind direction (°)**
Santa Ana-Large fire	5.19	38.51
Santa Ana-No large fire	3.96	33.54
No Santa Ana-Large fire	2.30	234.21
No Santa Ana-No large fire	2.38	236.94

B. Correlation and Regression of Santa Ana Winds As a Cause of Fires in Southern California

The relationship between Santa Ana winds and wildfires in Southern California has been studied extensively, with studies showing a significant correlation and causal relationship between the winds and increased fire activity affecting a large area of up to 23,000 ha [13]. Studies conducted from 2001 to 2009 found that wildfires during Santa Ana winds were 3.5 to 4.5 times larger than fires on non-Santa Ana days. Wildfires are likely to occur in the fall when vegetation dries out and becomes highly flammable. Very low humidity and high peak wind speeds can also increase the potential for fires. Climate change, resulting from rising global temperatures, may increase the likelihood and intensity of conditions that lead to wildfires in Southern California

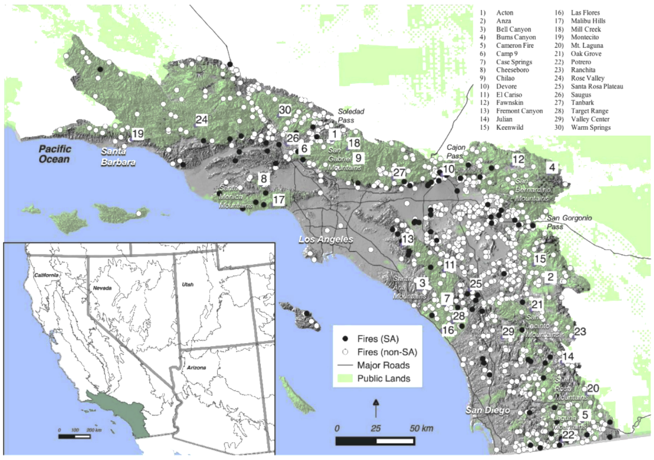

Figure 1. Location of meteorological stations as a reference for measuring average wind speed and wind flow direction [12]

C. Energy Infrastucture and Policy Analysis

An analysis of infrastructure and energy policy in Southern California has the potential to spark a fire that could impact a vast area. Power lines located above ground that are broken have been identified as a potential cause of major fires [14]. These power lines are more vulnerable to weather and falling trees. High wind speeds are a challenge for cable support poles, and the weight of the cables themselves causes short circuits. Public supervision seeks to place cable installations as electrical energy distribution underground to anticipate short circuits that can easily burn anything that is dry and flammable [15]. Undergrounding is much safer but also expensive, causing utilities to delay and avoid these investments. On the other hand, utilities are slow to act preventively during high-risk conditions. Local governments often oppose undergrounding or large-scale utility changes for aesthetic or economic reasons, thus inhibiting safer infrastructure improvements.

IV. Conclusion

Extreme climate change has recorded repeated disaster events, especially in the state of California. The region has experienced extensive and repeated forest fires, even dubbed the deadliest wildfires that occurred in January 2025, which scorched thousands of acres and displaced over 100,000 people.

Failure of electrical infrastructure and energy policies are the main actors considered to be the triggers of the fires. The existence of the Santa Ana wind phenomenon is also considered to have contributed to enlarging and expanding the fires. Energy policy plays a crucial role in regulating the electricity network, preventing disaster risks, and maintaining environmental safety from accidental disasters.

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REFERENCES

[1] "Johnson & Johnson Climate Friendly Energy Policy".

[2] National Weather Service, "Mountain and Valley Winds," Silver Spring.

[3] N. Wasserman and S. E. Mueller, "Climate influences on future fire severity: a synthesis of climate-fire interactions and impacts on fire regimes, high-severity fire, and forests in the western United States," Dec. 01, 2023, *Springer Science and Business Media Deutschland GmbH*. doi: 10.1186/s42408-023-00200-8.

[4] K. Calvin *et al.*, "IPCC, 2023: Climate Change 2023: Synthesis Report, Summary for Policymakers. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland.," Jul. 2023. doi: 10.59327/IPCC/AR6-9789291691647.001.

[5] F. Taccaliti, R. Marzano, T. L. Bell, and E. Lingua, "Wildland–Urban Interface: Definition and Physical Fire Risk Mitigation Measures, a Systematic Review," Sep. 01, 2023, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/fire6090343.

[6] CAL FIRE, "2025 Incident Archive," California, 2025.

[7] M. T. Hossain *et al.*, "Next generation power inverter for grid resilience: Technology review," Nov. 15, 2024, *Elsevier Ltd*. doi: 10.1016/j.heliyon.2024.e39596.

[8] US. Department of Energy, "Resilient Power Grids: Strategically Undergrounding Powerlines," 2022.

[9] Z. Sa'adi *et al.*, "Enhancing climate change-induced flood co-adaptation in the Johor river basin, Malaysia: A dotmocracy mapping approach with key technical stakeholders," *Environ Sci Policy*, vol. 165, p. 104015, Mar. 2025, doi: 10.1016/j.envsci.2025.104015.

[10] *Ensuring safety and health at work in a changing climate Global report*. 2024. [Online]. Available: www.ilo.org/publns.

[11] A. M. Brockway and L. N. Dunn, "Weathering adaptation: Grid infrastructure planning in a changing climate," *Clim Risk Manag*, vol. 30, p. 100256, 2020, doi: 10.1016/j.crm.2020.100256.

[12] A. W. Dye, J. B. Kim, and K. L. Riley, "Spatial heterogeneity of winds during Santa Ana and non-Santa Ana wildfires in Southern California with implications for fire risk modeling," *Heliyon*, vol. 6, no. 6, p. e04159, Jun. 2020, doi: 10.1016/j.heliyon.2020.e04159.

[13] J. E. Keeley *et al.*, "Climate and weather drivers in southern California Santa Ana Wind and non-Santa Wind fires," *Int J Wildland Fire*, vol. 33, no. 8, Aug. 2024, doi: 10.1071/WF23190.

[14] "Electrical System Safety," 2022. [Online]. Available: www.auditor.ca.gov

[15] H. Eagleston, M. Bester, J. Yusuf, A. Damodaran, and M. J. Reno, "Systemic Drivers of Electric-Grid-Caused Catastrophic Wildfires: Implications for Resilience in the United States," *Challenges*, vol. 16, no. 1, p. 13, Feb. 2025, doi: 10.3390/challe16010013.

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